

Published in final edited form as:

J Nov Physiother. 2013 February 28; Suppl 3: 001–. doi:10.4172/2165-7025.S3-001.

Isokinetic Strength and Performance in Collegiate Women's Soccer

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Abstract

Soccer research in exercise science has focused on men's soccer, while women's soccer has been underrepresented in training studies, as well as in studies focusing on physiological variables. The purpose of this study was to examine anthropometric data and selected physiological and biomechanical variables of importance as they correlates to performance variables such as ball velocity and distance, specifically in female collegiate soccer players. Twenty-two NCAA Division I female soccer athletes participated in the study. Body composition, muscular strength, explosive power, aerobic power, acceleration, speed, and agility were tested in each athlete. Knee torque (KT) and hip torque (HT) were also measured on both legs. Kicking accuracy and velocity were examined. A correlation was found between KT and KV ($r=0.93$), as well as vertical jump and KV ($r=0.91$). Aerobic power ($r=0.93$), agility ($r=0.88$), and vertical jump ($r=0.84$) were highly correlated to BF%. These data suggest that significant relationships do exist between peak knee and hip torque, agility, lean body mass, strength, and explosive power with soccer-specific variables such as kick velocity (KV). Contributing to the body of data on female soccer athletes and variables important in performance is essential as the population engaged in the sport continues to increase.

Keywords

Female soccer; Collegiate; Hip and knee torque; Performance variables

Introduction

Soccer research in exercise science has focused on men's soccer, while women's soccer has been underrepresented in training studies, as well as in studies focusing on physiological variables. This disparity limits growth in advancing sports performance research for women's soccer. Women now account for over 22% of soccer players worldwide and close to 40% of soccer players in the United States. With introduction of the Women's Professional Soccer league in 2008, there is now an increasing demand for the scientific investigation of the female game and of the players, with match analysis and role variations

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requiring particular attention. Considering the increases in the collegiate women's game, professional women's game, and the Olympic game there is a disproportionate amount of research into physiological demands and the physical characteristics of players.

Most normative data in the female soccer game has been match analysis, common injury related research, mainly focusing on ACL tears of female soccer players and nutritional analysis. Few studies have exposed research focusing mainly on kicking performance of female soccer players. Reilly and Durst [1] found that peak muscle torque and angular velocity had very high correlations during kicking. While other research has focused on the joint rotations and muscular movement of female soccer player's kick as opposed to male soccer player's kick [2]. Normative data for female soccer players is an essential process to gather information for player profiling. By evaluating a player based on a fitness profile, a coach can adapt the appropriateness and progression of the training regime to apply it to the specific needs of the player to improve on field performance.

Normative data on women's soccer and kicking is limited. Therefore the purpose of this study was to determine the relationship among isokinetic knee and hip torque, various physiological and biomechanical characteristics, and soccer-specific variables in female collegiate soccer players.

Methods

Twenty-two NCAA Division I female soccer athletes participated in the study. Data was collected preseason and immediately post-season. The human subjects review board at Louisiana Tech University, along with the head soccer coach and athletic director, granted approval for the study to be conducted.

Anthropometric data was collected on age, height, weight, and body composition. Body composition was assessed using the Jackson-Pollock 3-Site skinfold method and equation, with Lange skinfold calipers. A one repetition max (1-RM) squat parallel test was used to determine the maximum lower body strength of the athlete. Lower body explosive power (VJ) was measured using a Vertec jump device. A 40-yard dash was measured to evaluate acceleration, and a 100 meter sprint time was used to determine speed. VO_2 max was tested in the Applied Physiology laboratory, using breath by breath analysis, on a Cosmed metabolic system. A two-mile run field test was also conducted to estimate aerobic power. Player agility was tested using the Illinois Agility Test.

Knee torque (KT) and Hip Torque (HT) were measured using knee and hip flexion and extension on the Biodex IV Isokinetic Machine. Subjects performed concentric contractions and were tested on each leg. The protocol included a warm-up followed by 3 repetitions at 30, 60, or 90 degrees per second. Subjects were counterbalanced and randomized into a group performing either by 30, 60, or 90 degrees per second set first.

A soccer performance test protocol for kicking accuracy and velocity was developed during this study. Kicking performance was evaluated by measuring maximal and mean velocity of the ball within the number of times the ball hits the target. Ball velocity was measured using a speed gun device located 1.22 meters above the ground, behind the goal. The gun was set

behind the goal as the speed at which the ball enters the goal area is most important for scoring opportunity. All subjects performed a standard dynamic warm-up prior to kicking. They completed 10 trials of maximal effort. The ball was required to clear a five foot barrier (to replicate a defensive wall during free kicks) ten yards away (as allowed by the governing body of soccer, FIFA). The ball was kicked with the dominant leg. The trial was only counted if it cleared the wall and enters the goal. The free kick was taken from 40 yards away from the goal frame. Statistical significance was set at an alpha level of $p = 0.05$.

Correlation coefficients (Pearson's r) were calculated for all variables by utilizing a correlation matrix from raw scores for both the pre and post season data.

Results

Many important correlations are recognized in the study, although not all are highly significant relationships. Highly correlated was defined as a correlation coefficient of 0.80 and higher; moderately high correlation was defined as 0.60–0.80. Moderate correlations were those from 0.40–0.60, while low correlation was below 0.40.

Statistical analysis indicated significant relationships exist. Descriptive data is reported in table 1. A correlation matrix of variables is reported in table 2. A correlation was found between KT and KV ($r=0.93$), as well as vertical jump and BV ($r=0.91$). Aerobic power ($r=0.93$), agility ($r=0.88$), and vertical jump ($r=0.84$) were highly correlated to BF%.

Discussion

Many coaches equate kicking performance, as measured by velocity and distance, to successful soccer players. Kicking is the one of most fundamental and easily assessed skills in soccer. Free kicks are one of the most useful offensive tools in scoring during a soccer game. The current results suggest that significant relationships do exist between the physiological characteristics of peak muscle torque, agility, lean body mass, strength, and explosive power with soccer-specific variables related to kicking, such as ball velocity (BV), which is similar to previous research [2,3]. Ball velocity is an important variable in soccer that may predict success or failure. The BV was highly correlated with knee torque in the current study. Hip torque was not as highly correlated with BV. This may indicate that knee flexion plays a more significant role in kicking velocity of female soccer athletes than hip flexion. Agility, strength, power, and lean body mass were all highly correlated with BV. These variables would be highly desirable in a female soccer player due to the high correlation with BV, which is a possible predictor of game success.

Agility is moderately to highly correlated with several variables, including speed, torque and power. Linear speed for 40 m and 100 m is correlated to agility performance, though only moderately correlated. The dynamic nature of soccer requires not only the possession of speed but of agility also. Browder et al. [2] showed that the greater rotational range of the pelvis for female soccer players produced a higher velocity kick. Further research [3] found that females rely mainly on pelvic rotation to enhance the speed of their kick, unlike males who rely on joint extension of the knee and hip. The ability for the female soccer player to rotate her hips and agility of the pelvis has shown to increase kick distance and velocity

Body composition is an important variable related to soccer fitness as excess adipose tissue acts as dead weight in activities in which body mass must be lifted repeatedly against gravity or moved over distances. The leaner the soccer player the less mass she has to move. Among NCAA Division I soccer players, the average percent body fat is 16% [4]. Lean body mass has a relationship with power output of athletes. By increasing lean body mass, the athlete may have a greater power output which can increase the velocity of the significance. The current data indicates that lower body fat is very highly correlated to aerobic capacity. A soccer game can last between 90 and 110 minutes. During this time the players are mostly jogging and sprinting. The aerobic system is a main source of energy provision during a soccer match. Research reported the average values of VO_2 max for top-level soccer players tend to be high, supporting the belief that there is a large contribution from aerobic power to playing the game. Krustup et al. [5] found that the average elite female soccer player runs an average distance of 9.7–11.3 km in the 90 minute game. A measurement of the athlete's VO_2 max is necessary to expose how well she can sustain energy throughout the game. In the current study, the leaner athletes had higher aerobic capacities, and produced more power, which supports previous research.

Strength (maximum and explosive) is another factor that plays a critical role on the performance of soccer skills. Cabri et al. [4] has reported a significant relationship between leg strength and kick performance indicated by the distance the ball traveled. Previous research [6] found similar findings, but additional findings included the lower limb strength having a stronger correlation with ball velocity and not distance. Other research has shown that when the synergy of the hip and lower limb strength development is maintained, improvements in lower limb strength and ball velocity are expressed [1,7]. Hip and knee torque are highly correlated in the current study, as were body fat and vertical jump height. The greater lower body strength translates into higher power. Strong correlations between strength and power are consistent in the current data.

Conclusion

The game of soccer places a varying demand of physiological factors on the performers. Each player must perform a diverse collection of dynamic movements including jumping, cutting, heading, sprinting, jogging, and the most fundamental and frequently used element of kicking. The possession of these fitness characteristics in isolation does not predispose the athlete for success in soccer; instead there must be a balance between these components. A fitness profile of the athletes may be generated from a battery of tests that will have some value in allowing comparisons between individuals and, with the use of normative ranges, individual weakness can be assessed and remedial training can be prescribed to increase performance.

Soccer-specific variables are highly correlated to peak muscle torque, agility, lean body mass, strength, and explosive power in female soccer athletes. However, one cannot interpret this to be a causal relationship. Although sport-specific skill training is essential and desirable among coaches and athletes, it is important to recognize that athleticism is multifaceted. The possession of these fitness characteristics in isolation does not predispose the athlete for success in soccer; instead there must be a balance between these components.

Using the performance tests discussed, and monitoring the athletes can help coaches' to determine which variables need improvement. Contributing to the body of data on female soccer athletes and physiological variables important in performance is essential as the population engaged in the sport continues to increase. Additionally, this research demonstrates a need for further research regarding hamstring to quadriceps strength ratio. Biodex isokinetic data suggest hamstring strength is half that of quadriceps strength. This has an important implication for strength coaches in conditioning athletes for injury prevention.

Acknowledgments

The authors work cited in this article was funded in part by: NIH P20 RR016457

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Table 1

Mean Characteristics of Participants.

Age (yr)	Wt (kg)	Ht (cm)	Illinois Agility (s)	1 RPM Squat lb	40 yrd dash (s)	100 m sprint (s)	VJ (in)	VO ₂ max	%BF	KT (Nm) (60 deg/sec)	HT (Nm) (120 deg/sec)	BV
20.1	62.9	165	16.1	189	5.63	14.1	18.2	43.5	20.8%	473.3	375.2	55.6

Table 2

Correlations between physiological characteristics and soccer specific skills.

	Illinois Agility	1 RPM Squat	40 yrd dash	100 m sprint	VJ	VO ₂ max	%BF	KT	KV	HT
Illinois Agility	1									
1 RPM Squat	0.52	1								
40 yrd dash	0.61	0.32	1							
100 m sprint	0.56	0.46	0.74	1						
VJ	0.43	0.64	0.53	0.46	1					
VO ₂ max	0.55	0.43	0.42	0.37	0.35	1				
%BF	0.88	0.35	0.57	0.62	0.84	0.93	1			
KT	0.63	0.67	0.75	0.69	0.58	0.51	0.42	1		
BV	0.34	0.74	0.65	0.54	0.91	0.45	0.64	0.93	1	
HT	0.57	0.54	0.78	0.64	0.74	0.68	0.53	0.81	0.69	1